

CS1010 Programming Methodology

Week 12: Recursion

Being ignorant is not so much a shame, as being unwilling to learn.
~ Benjamin Franklin

To students:

- Recursion is an important topic which will be used very often in the next module CS2040. Hence it is very important that you learn the basics of recursion well.
- Please also be reminded that PE2 is on **4 Nov (Sat)**. Please check out the CS1010 website PE page for more information.

1. Tracing recursive codes

(a) [AY2010/2011 Semester 1 Exam, Q1.2]

Given the following function, what does **f(5)** compute?

```
// Precond: n >= 0
int f(int n) {
    if (n == 0)
        return 0;
    else
        return (2 * n + f(n-1));
}
```

(b) Trace the function below manually, and write out the return value of **q(12)**.

```
// Precond: n >= 0
int q(int n) {
    if (n < 3)
        return n+1;
    else
        return q(n-3) + q(n-1);
}
```

Exploration: Would you be able to write an iterative version? Run both versions on large input, such as 50. What do you observe?

(c) [AY2011/2012 Semester 1 Exam, Q1.5]

What does following function compute?

```
int mystery(int x, int y) {
    if (x == 0)
        return y;
    else if (x < 0)
        return mystery(++x, --y);
    else
        return mystery(--x, ++y);
}
```

- A. It returns the value of y.
- B. It returns the value of $x - y$.
- C. It returns the value of $x + y$.
- D. It returns the value of $x * y$.
- E. It will give compile-time error.

2. Summing digits in an integer.

Summing digits in a non-negative integer n can be easily written using a loop. Is writing a recursive code for it just as easy? Write a recursive function `int sum_digits(int n)` to sum up the digits in n . (This question is discussed in lecture so this is some kind of revision.)

A sample run is shown below:

```
Enter a non-negative integer: 970517
Sum of its digits = 29
```

3. Recursion on array

Study the program `q3.c` below and trace the recursive function `mystery(int [], int)`.

What is the smaller version of the task on which the recursive call works? How does the original problem relate to this smaller problem? What does the function compute?

```
... // Omitted for brevity

int main(void) {
    int list[SIZE];
    scan_array(list, SIZE);
    printf("Answer = %d\n", mystery(list, SIZE));
    return 0;
}

// Read in values for array arr
void scan_array(int arr[], int size) {
    int i;

    printf("Enter %d values: ", size);
    for (i=0; i<size; i++)
        scanf("%d", &arr[i]);
}

// Precond: n > 0
int mystery(int arr[], int n) {
    int m;

    if (n == 1)
        return arr[0];
    else {
        m = mystery(arr, n-1);
        return (arr[n-1] > m) ? arr[n-1] : m;
    }
}
```

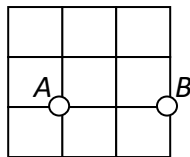
4. [AY2010/2011 Semester 1 Exam, Q4]

Write a recursive function **int largest_digit_pair(int n)** to determine the largest pair of digits of a positive integer **n** starting from the right to the left.

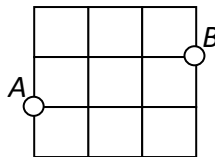
For example, if **n** is 5064321, then the pairs are 21, 43, 6 and 5, and hence the answer is 43.

5. **North-East Paths**

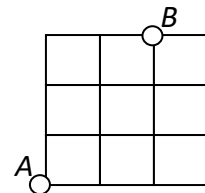
In a special town where pedestrians are only allowed to move northwards or eastwards, each of the following examples shows the total number of unique NE-paths, **ne(x, y)**, to get from point **A** to point **B**, where **B** is **x** rows north and **y** columns east of **A**. Assume that **x** and **y** are non-negative integers. By convention, **ne(0, 0) = 1**.



$$\text{ne}(0, 2) = 1$$



$$\text{ne}(1, 3) = 4$$



$$\text{ne}(3, 2) = 10$$

Write a recursive function **int ne(int, int)** to compute the number of NE-paths.

The following are some sample runs.

```
Enter rows and columns apart: 0 2
Number of NE-paths = 1
```

```
Enter rows and columns apart: 1 3
Number of NE-paths = 4
```

```
Enter rows and columns apart: 3 2
Number of NE-paths = 10
```

6. **Reversing an Array**

Write a program **reverse_array.c** to randomly assign values into an integer array, and then reverse the array using recursion.

For example, if the array contains { 6, 3, 0, 6, 8, 1, 5 }, then the reversed array is { 5, 1, 8, 6, 0, 3, 6 }. You should not use any additional array. You may assume that the array contains at most 15 elements.

7. [AY2012/2013 Semester 1 Exam, Q4]

A positive integer can always be expressed as a product of prime numbers. For instance,

$$\begin{aligned} 60 &= 2 \times 2 \times 3 \times 5 = 2^2 \times 3^1 \times 5^1 \\ 78 &= 2 \times 3 \times 13 = 2^1 \times 3^1 \times 13^1 \\ 13 &= 13 = 13^1 \end{aligned}$$

The following function **countPrimes()** takes a positive integer and counts the number of (possibly duplicate) prime numbers required to form the given integer.

countPrimes(60) returns 4 (two 2's, one 3 and one 5)
 countPrimes(78) returns 3 (one 2, one 3 and one 13)
 countPrimes(13) returns 1 (one 13)

```
int countPrimes(int number) {
    return countPrimesRec(number, 1, 0);
}
```

This function in turn calls a recursive function **countPrimesRec()** that does the job of counting primes. The partial code for **countPrimesRec()** is given. You are to complete it by filling your code and the pre-conditions in the dashed boxes.

Note that function **getPrime(*i*)** is considered given, which returns the *i*-th smallest prime number. For instance:

getPrime(1) returns 2; getPrime(2) returns 3; getPrime(3) returns 5

```
// Pre-conditions:
// [dashed box]
// [dashed box]
int countPrimesRec(int number, int index, int count) {
    int prime;

    if (number == 1)
        return count;
    prime = getPrime(index);
    if (number % prime) {
        [dashed box]
    }
    else {
        [dashed box]
    }
}
```

8. [AY2015/2016 Semester 1 Exam, Q13]
Observe the pattern in the following 2D arrays.

1

n = 1

1	2
2	2

n = 2

1	2	3
2	2	3
3	3	3

n = 3

1	2	3	4
2	2	3	4
3	3	3	4
4	4	4	4

n = 4

1	2	3	4	5
2	2	3	4	5
3	3	3	4	5
4	4	4	4	5
5	5	5	5	5

n = 5

Write a recursive function `fill(int arr[][20], int n)` to fill a $n \times n$ 2D array `arr` with the pattern shown above.

You may assume that n is an integer in $[1, 20]$.

9. Rewrite the binary search program using recursion. Use an auxiliary function as suggested in the lecture.